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The Effect of Land Use Types on Various Forms of Phosphorus in the Gashua Area of Bade Local Government of Yobe, Nigeria

Sunday Dogo*[1], Aisha Rabilu[2], Ibraheem Alhassan[3]

[1,2,3] Federal University Gashua, Yobe Nigeria.

ABSTRACT

Increasing concern on the role of phosphorus in crop production across fields of agricultural research call for concern. This study assesses the effect of land use types on various forms of soil phosphorus in Gashua. Soil samples were collected across three different locations namely forested land (FL), bare land (BL), and cultivated land (CL) from 0–15 cm and 15-30cm depth. ANOVA was used to show the significant difference between the variables. The results from the study area showed Available phosphorus (A-P) with values ranging from 8.33 mg kg^{-1} to 8.57 mg kg^{-1}. Bulk density remained stable 1.20-1.42 gcm^{-3}, and pH values 6.60 - 7.40 indicated slightly alkaline conditions. Electrical conductivity (EC) varies between 0.09 - 0.19, suggesting low salinity. Organic carbon content of the study area ranged from 0.70% to 1.18%. Phosphorus fractions from the study revealed that calcium-phosphorus (Ca-P) was highest in forested regions with 20.63 mg kg^{-1} while iron-bond phosphorus (Fe-P) was higher in bare land with value of 14.84 mg kg^{-1}. Aluminum-bound phosphorus (Al-P) recorded a maximum value of 143 mg kg^{-1} in cultivated land, and organic phosphorus (Or-P) recorded a maximum of 65.55 mg kg^{-1} in bared land. Total phosphorus (T-P) was higher in both cultivated land and bare-land with 143.85 mg kg^{-1} and 140.06 mg kg^{-1} and forested areas showed an appreciably decreased values of 98.27 mg kg^{-1}. The study Concluded that there were no variations in A-P, Ca-P, and Fe-P throughout the land use types, while the Al-P and Or-P show higher variations.

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Corresponding Author:
Sunday Dogo

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INTRODUCTION

Land use is one of the most critical inputs to agricultural activities, be it crop production or livestock, where phosphorus plays a key role. There is increasing attention on the role of phosphorus in crop nutrition across numerous fields of agricultural research. This is because Phosphorus (P) is an essential nutrient that often limits plant productivity, especially in tropical regions (Elser *et al.,* 2007; Vitousek and Howarth, 1991). Unlike nitrogen (N), which is supplied by N fixers or directly from the atmosphere in fixed form, the primary source of P for terrestrial ecosystems is rock weathering. Therefore, P has been considered the ultimate limiting soil nutrient in terrestrial ecosystems. This is because of the major differences between crops in their ability to take up different forms of phosphorus, numerous inorganic and organic forms of P that occur in soils, as well as the wider variation in behavior between soil types, are some of the factors militating against the proper understanding of phosphorus behaviors in soil. This recent development has led to renewed interest in crop-soil availability of phosphorus, which is a major problem in agricultural crop production. However, Phosphorus (P) is recognized as one of the most limiting factors in plant growth and productivity on a worldwide basis (World Bank, 1998). Phosphorus deficiency is particularly widespread and remains a major plant nutrient constraint in rain-fed upland farming systems throughout the tropics. Accordingly, Sanchez and Salinas (1981), Buresh (2016), and Fairhurst *et al.* (1999) stressed that phosphorus is an essential element in the management and sustainability of upland land use systems in the tropical environment. As a result, considerable progress has been made in the tropics in recognizing the importance of phosphorus supply, understanding the process of phosphorus availability and cycling, studying phosphorus fertilizer application rates, application methods, and management options, and developing techniques for studying its availability, uptake, and cycling are vital keys for consideration.

The aim of this paper is to critically analyses the effect of land use types on various forms of soil phosphorus. The specific objective of this research was to study the effect of various forms of soil phosphorus under different land use types in the Gashua district of Bade, Yobe, Nigeria.

MATERIAL AND METHOD

Description of the study area

The study was conducted in Gashua, District of Bade Local Government, Yobe State, in the Northeast of Nigeria. Gashua is in the Sahelian ecological zone of Nigeria, located between latitude 12.75° to 12.95° N and longitude 11.00° to 11.15oE °E, with an average altitude of 299 meters above sea level.

Climatic conditions of the study area.

The climate of Gashua is characterized by both wet and dry seasons. The wet season is hot, oppressive, and mostly cloudy, and the dry season is sweltering, windy, and partly cloudy. Over the course of the year, the temperature typically varies from*59°F*to*105°F*and is rarely below*53°F*or above*109°F.* The hot season lasts for 2.5 months, from March 26 to June 11, with an average daily high temperature above101°F. The hottest month of the year in Gashua is May, with an average high of104°Fand a low of82°F.The cool season lasts for 1.7 months, from December 10toFebruary 2, with an average daily high temperature below89°F. The coldest month of the year in Gashua is January, with an average low of60°Fand a height of 87°F. A wet day is one with at least 0.04 inches of liquid or liquid-equivalent precipitation. The chance of wet days in Gashua varies significantly throughout the year.

vegetation and Land use of the Study Area

The major vegetation type in the Gashua consists of an open thorny savannah with short trees and grasses. The trees are about 5 to 10m high (Alhassan *et al*., 2018).

The land use in the Gashua area is diverse, encompassing agricultural lands (both rain-fed and irrigated in fadama areas), rangelands for livestock grazing, residential areas, and patches of natural vegetation. Agricultural practices vary across these land-use types, with lowland areas often experiencing more intensive cultivation and management compared to the dry uplands Land, which significantly influences soil properties, with variations observed in texture, nutrient content, and organic matter accumulation across different land management regimes (Busari *et al.,* 2021).

Geology of the study area

The geology of the Gashua region is primarily characterized by the Chad formation, which is part of the larger Chad Basin. The topography within few miles of Gashua is essentially flat, with a maximum elevation change of 72 ft and an average elevation above sea level of 299 ft. Within 10 miles is also essentially flat (72 ft). This formation is composed mainly of unconsolidated sedimentary deposits of tertiary to quaternary age that typically include sands, silts, and clays, which have been laid down in lacustrine (lake) and fluvial (river) environments (Offodile, 1992).

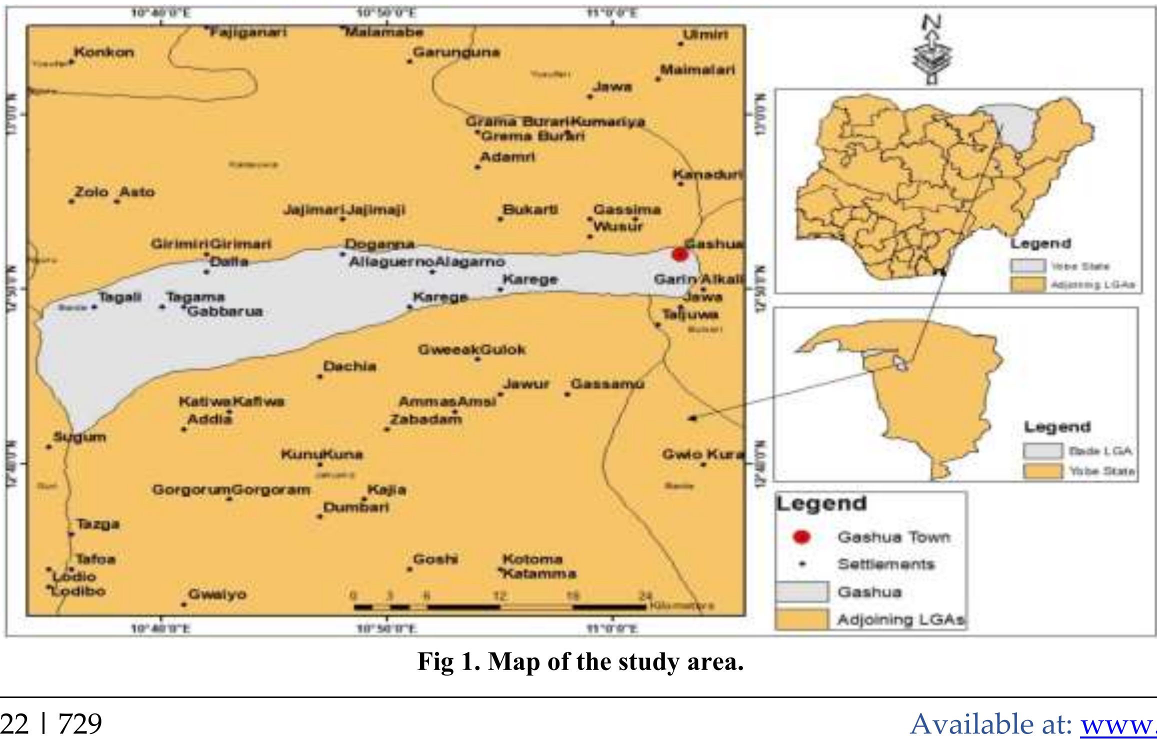

Fig 1. Map of the study area.

EXPERIMENTAL SITE

The research experimental sites comprise three (3) different land use types, such as bare land, cultivated land, and forested land, through which all forms of phosphorus, including Aluminium-bound Phosphorus(Al-P), Iron-bound Phosphorus(Fe-P), Calcium-bound Phosphorus (Ca-P), Total Phosphorus (T-P), Organic Phosphorus(Or-P), and Available Phosphorus(A-P), were studied in the soil using descriptive means on their suitability for crop production.

SOIL SAMPLING

Soil samples were collected within the Gashua district of Bade, Yobe, Nigeria, during the rainy season at three (3) different locations, namely forested land (FL), bare land (BL), and cultivated land (CL) at depths of (0–15 cm) and (15-30cm) using a soil auger.
The collected samples were then put in a tie polyethene bag, labeled, air dried, and then taken to the laboratory for further analyses after all the precautions were observed.

LABORATORY ANALYSIS

The air-dried soil samples were ground to pass through 2mm sieves as required by specific analytical procedures. The soil samples were analyzed for their physicochemical properties following standard laboratory procedure. The Particle size distribution was analysed by the hydrometer method following the procedure described by Ekanade (2019). Soil pH was measured potentiometrically using a pH meter in the supernatant suspension of a 1:2.5 soil-to-water ratio. Organic carbon was determined following the wet digestion method as described by Agbo-Adediran *et al* (2019). whereas the Kjeldahl procedure was used for the determination of total nitrogen as modified by Ogunleye *et al.* (2014). Available Phosphorus was extracted by the modified Ogunleye *et al* (2014) extraction methods. Total phosphorus was extracted using the aqua regia digestion technique, whereas inorganic phosphorus fractions were successively extracted: saloid-P with 1 M NH4Cl, saloid P, aluminium-bound P (Al-P) with 0.5 M NH4F, iron-bound P (Fe-P) with 0.1 M NaOH, calcium-bound P (Ca-P) with 0.25 M H2SO2, reductant soluble iron-bound P (R-Fe-P) with 0.3 M Na-dithionite and Na-citrate solution, and occluded aluminium-iron-bound phosphorus (occl-Al-Fe-P) with 0.1 M NaOH Ekanade, 2019). The organic phosphorus of a sample was determined by the difference between phosphorus extracted with H2SO4 from calcinated and non-calcinated soil. The different forms of soil phosphorus extracted with the different methods were measured by a spectrophotometer following the procedure outlined by Alhassan *et al* (2018).

STATISTICAL ANALYSIS

All analyses were carried out using SPSS version 26. ANOVA analysis was used to compare the relationship between the sets of independent variables and the dependent variable. To see if there is a significant difference among various forms of phosphorus across the different land-use types. Why the Post-Hoc test is used for the means separation.

RESULT AND DISCUSSION

Table 1: Physico – Chemical Properties of the Different Land Use Types

Land use	Land use	Depth	pH	EC	OC	OM	Db	A-p	Ca-p	Fe-P	Al-p	T-p	Or-p
1	1	1	6.60	0.09	1.05	0.59	1.38	7.31	17.37	13.34	148.33	10.33	67.00
1	2	2	6.60	0.13	0.80	0.52	1.22	9.22	17.37	13.37	148.33	10.33	67.30
1	1	1	6.92	0.09	1.18	0.53	1.42	7.44	18.88	12.33	139.37	12.83	63.88
1	2	2	6.92	0.12	0.70	0.59	1.20	9.27	18.89	12.80	139.37	12.83	63.91
2	1	1	7.20	0.10	0.78	0.49	1.28	8.41	21.27	15.05	142.36	16.35	61.95
2	2	2	6.80	0.19	1.03	0.45	1.20	9.19	21.27	15.33	142.36	16.35	61.98
2	1	1	7.01	0.10	0.77	0.60	1.21	8.21	12.39	14.35	137.77	12.39	69.21
2	2	2	6.92	0.19	1.04	0.58	1.21	9.19	12.22	14.59	137.77	12.39	69.35

3	1	1	6.80	0.10	0.90	0.39	1.35	9.22	20.48	12.19	96.67	10.19	60.10
3	2	2	7.40	0.18	0.85	0.39	1.32	9.70	20.48	12.19	96.67	10.19	60.09
3	1	1	6.80	0.10	0.93	0.44	1.36	8.92	20.77	11.99	99.86	10.11	60.99
3	2	2	7.40	0.18	.88	0.42	1.29	9.51	20.77	11.93	99.86	10.11	61.18
Mean			6.94	0.13	0.90	0.50	1.29	8.80	18.5	13.30	127.40	12.03	63.91
Std			0.85	0.52	0.27	0.42	0.10	0.08	3.78	1.25	21.81	2.31	3.45
SE			0.08	0.01	0.04	0.02	0.23	0.23	0.93	0.36	6.30	0.67	0.10

EC= Electrical conductivity, OC = %organic carbon, OM= % organic matter, Db= Bulk density, A-P= available Phosphorus, Ca-p= Calcium Phosphorus, Fe-P= Iron phosphorus, Alp= Aluminium phosphorus, T-p= Total phosphorus, Or-p= Organic Phosphorus. 1=cultivatedland,2=bareland,3=forested land (for land use types) while 1= 0-15 and 2=15-30cm (as in soil Depth).

Table 2. Mean Comparison of Various Forms of Soil Phosphorus Under Different Land use

Land uses types	A-P	Al-P	Ca-P	Or-P	Fe-P	T-P
BL	8.330a	11.495b	18.400a	65.780b	13.040a	117.045a
CL	8.495a	12.785a	18.995a	69.445a	13.435a	123.155a
FR	8.565a	11.560b	18.895a	69.435a	14.095a	122.550a
SE	0.58	0.21	0.21	0.59	0.33	1.51
Pr(>f)	0.96	0.035	0.25	0.034	0.22	0.11
CV%	9.75	2.43	1.58	1.22	3.48	1.76

BL= Bear Land, CL= Cultivated Land, FR= Forested Area, A-P= Available Phosphorus, Al-P= Aluminum Phosphorus, Ca-P= Calcium Phosphorus, Or-P= Organic Phosphorus, Fe-P= Iron Phosphorus and T-P= Total Phosphorus.SE= Standard error, CV=Coefficient of variation.

The result shows that there is no significant difference in land use in the available phosphorus (AP) which ranges from (8.330 mg kg^{-1}) in bear land, (8.495 mg kg^{-1}) in cultivated land, and (8.565 mg kg^{-1}) in forested areas considered to be low according to Esu (1991) rating of <10 low, 10-20 medium and >20 high.

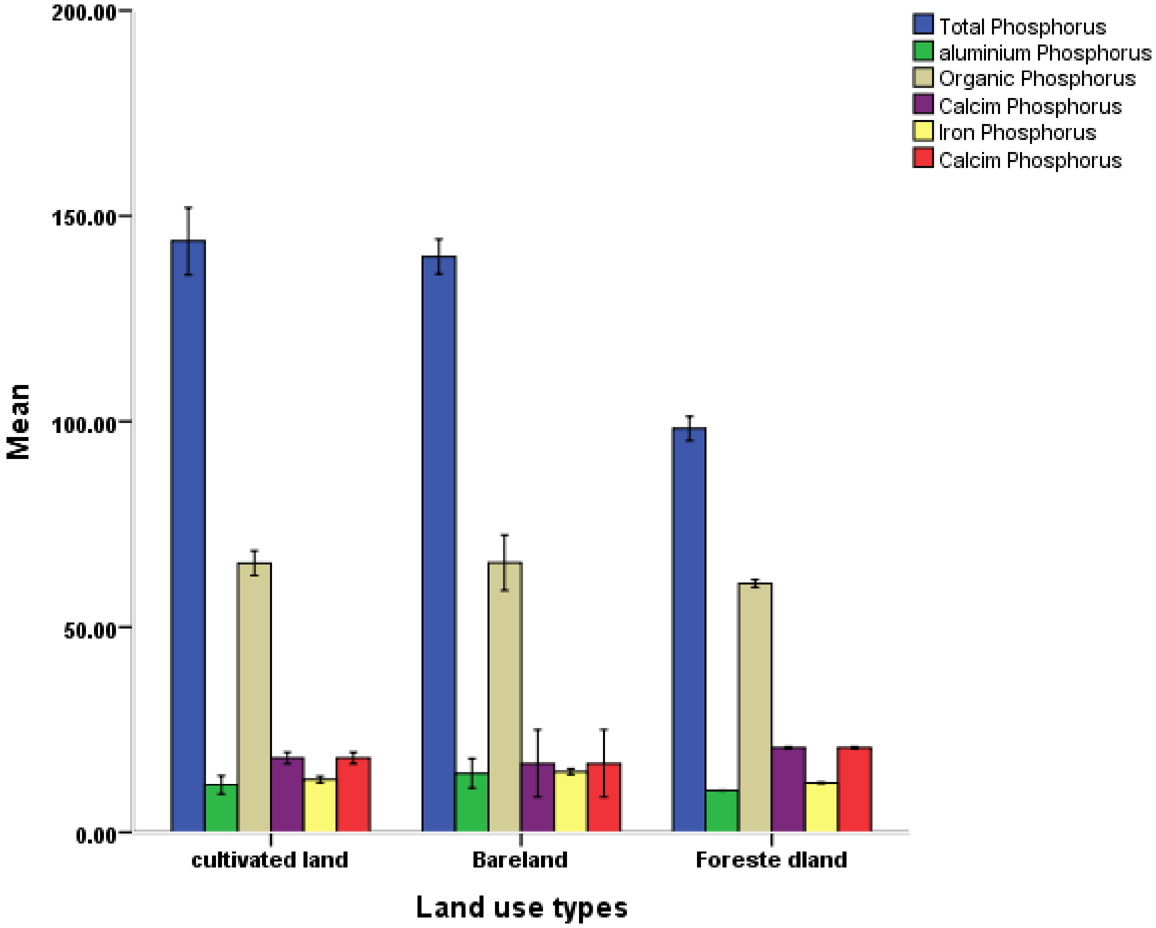

Fig 1: Mean difference in various forms of Phosphorus across the three land use types

Figure 1 shows the mean differences from various forms of phosphorus (Total Phosphorus, Aluminium Phosphorus, Organic Phosphorus, Calcium Phosphorus, Iron Phosphorus) across three different land-use types. The result from cultivated land, bare land, and forested land from this study reflects the distribution of phosphorus fractions and their interaction with different soil management practices across the land uses**.** Total Phosphorus (blue bars) demonstrated the highest in all land-use types, with the most significant values seen in bare land and cultivated land, followed by forested land. Calcium Phosphorus (light yellow bars) shows relatively high values across all land-use types, especially in forested land. Organic Phosphorus (purple bars) remains consistent but lower across the three land-use types, with slightly higher values in forested land. Iron Phosphorus (green bars) and Aluminium Phosphorus (orange bars) have smaller values, with little variation between land-use types.

pH, EC, Organic carbon and Organic Matter, and soil Bulk Density

From Table 1. The result of the pH values from the study ranges between 6.60 and 7.40, indicating neutral to slightly alkaline soil conditions across the land-use types. Gisandu et al (2022) discovered that the variations in these values were due to differences in soil management practices and land use intensity. The Electrical Conductivity (EC) shows variability from 0.09 to 0.19, suggesting low salinity across the land use types. The result Organic Carbon values range from 0.70 to 1.18%, while OM is generally lower in the deeper layers but varies from 0.39 to 0.60%. this agreed with Grossman & Mladenoff, (2008) who also reported similar results. The Bulk Density (Db) is relatively stable around 1.20 to 1.42 gcm-^{3}, with minor fluctuations between land uses. Greenwood & Buttle (2014) reported a similar finding that these variations were influenced by land-use practices, such as tillage and soil compaction in agricultural lands.

Available Phosphorus (Ap), Calcium-bound Phosphorus (Ca-P), and Iron-bound Phosphorus (Fe-P)

From Table 1, the result on the Available Phosphorus (Ap) is found to be slightly higher in forested areas, approximately 9.46 mgkg^{-1}, compared to cultivated lands with 8.29 mgkg^{-1} and bare-lands 8.70 mgkg-1. Sharma *et al.* (2017) indicated that available phosphorus levels in cultivated soils were generally higher than those in forest soils, this is primarily due to fertilizer usage. In their research, cultivated soils exhibited 13-20 mg kg^{-1} of available phosphorus, while forested soils had lower concentrations of 7 mg/kg, which contrasts with our finding that forested areas display slightly higher levels of available phosphorus of 9.46 mg kg^{-1}. intensively cultivated lands reported higher available phosphorus with 15 mg kg^{-1}. This agrees with general observations in cultivated lands.

Calcium-bound Phosphorus (C-ap) is find to be highest in forested land with 20.63 mg kg^{-1}, with bare-lands and cultivated areas demonstrating moderate levels of calcium bounded phosphorus**.** Zhang *et al* (2017) recorded calcium-bound phosphorus to be generally higher in forested areas, which is attributed to the natural cycling of calcium minerals from decomposing plant matter and reduced soil disturbance. From their findings, they also reported approximately 22 mg kg^{-1} in forested soils. This observation is further supported by Hedley et al (1982). who noted that calcium-bound phosphorus in forested soils surpasses that in cultivated regions, which may likely be a result of increased mineralization of organic matter and the absence of leaching.

The results on Iron-bound Phosphorus (Fe-P) recorded the highest concentrations in bare land with 14.84 mg kg^{-1}, whereas lower levels are found in forested areas with 12.06 mg kg^{-1}. Tiessen and Moir (1993) found that iron-bound phosphorus is typically more abundant in undisturbed soils, like those in forested settings, while agricultural soils exhibit reduced levels due to oxidation and phosphorus depletion from crop uptake. Pierzynski *et al* (2005). reported similar findings.

Aluminium-bound Phosphorus (Al-p), Organic-bound Phosphorus (Or-p), and Total Phosphorus (T-p)

From Table 1. The results on Aluminium-bound phosphorus is most prevalent in cultivated land with 143 mg kg^{-1}, followed by bare land, while forested areas exhibit significantly lower levels of 98.26 mg kg^{-1}. Lajtha and Harrison (1995) found that aluminum-bound phosphorus tends to be higher in cultivated soils due to fertilizer applications that enhance phosphorus fixation by aluminum oxides, they recorded a value range from 120 to 160 mg kg^{-1} in these areas, which agreed with our results that Al-p is prevalent in this land use type.

For the Organic-bound Phosphorus (Or-p), bare land contains the highest levels with around 65.55 mg kg^{-1} of Or-p, followed closely by cultivated land with 65.09 mg kg^{-1} of Or-p, while forested areas show the lowest amounts with 60.64 mg kg^{-1} of Or-p. Condron *et al.* (2011). also recorded higher organic phosphorus concentrations in soils, which is due to litter fall and leaf decomposition. However, their research noted that bare land might also accumulate organic phosphorus due to lower microbial activity, which also aligns with our results concerning bare land. The Total Phosphorus (T-p) levels are higher in cultivated land with 143.85 mgkg-1and 140.06 mg kg-1 in bare land, while forested land shows significantly lower concentrations with 98.27 mgkg-1. McGill and Cole (1981) reported that total phosphorus levels were considerably elevated in cultivated areas. This may be attributed to fertilizer application and other amendments, which also agreed with our findings. Walker and Syers (1976) suggested that total phosphorus in forested soils is naturally lower due to limited phosphorus input and higher fixation, which is also the same as our finding, where similar lower total phosphorus in forested land was recorded.

Relationship Between the Various Forms of Soil Phosphorus

From Table 2, the results on the analysis of variance (ANOVA) where demonstrated to show the relationship between the forms of soil phosphorus in the study area. The A-P levels are quite similar across Bare land with 8.330 mg kg^{-1}, and the cultivated land recorded 8.495 mg kg^{-1}, whereas forested land recorded 8.565 mg kg^{-1}. The p-value of 0.96 indicates no significant difference in various forms of phosphorus between the different land use types. The available phosphorus often shows variation, resulting from the excessive use of land, particularly in agricultural land where fertilizers are applied. For instance, studies in agricultural soils often show higher A-P levels due to fertilization, compared to forest soils where organic matter is the primary source of P. Azeez *et al* (2011). also recorded higher A-P in cultivated lands compared to forest soils due to increased phosphorus inputs through fertilization. The lack of significant differences in our findings may suggest that fertilizer inputs in cultivated land are not excessive, or that soil management practices are similar across land uses. Aluminium-bound Phosphorus (Al-P) shows that cultivated land has 12.785 mg kg^{-1}, having a significantly higher Al-P than bare land with 11.495 mg kg^{-1} and forested land recorded 11.560 mg kg^{-1}, with a p-value of 0.035. Aluminium-bound phosphorus (Al-P) is more abundant in acidic soils, as Al-phosphates, which form under low pH conditions. Several studies, such as those by Bünemann *et al.* (2016), highlight that forest soils, particularly in tropical regions, often have higher Al-P due to acidic conditions favoring the binding of phosphorus to aluminum oxides. However, our findings show a higher Al-P in cultivated lands, which may indicate that the soils under cultivation are not limed or treated to reduce acidity, which allowed Al-P to accumulate. Similarly, Smith *et al* (2021). found that aluminium-bound phosphorus increased in continuously cropped acidic soils due to limited liming. Calcium-bound Phosphorus (Ca-P) levels show similar results across land uses, with bare land having 8.40 mg kg^{-1}, cultivated land 18.95 mg kg^{-1}, and forested land show 18.89 mg kg^{-1}, having a p-value of 0.25, which mean no significant differences across the three land use types. Calcium-bound phosphorus (Ca-P) increases in soils with higher pH, such as those found in calcareous soils or where lime or phosphate fertilizers are applied. Studies by Tiessen *et al.* (1984) showed that Ca-P levels increase in cultivated lands due to the application of phosphatic fertilizers, especially in soils with neutral to alkaline pH. From our study, the similarity in Ca-P levels across land uses suggests that the soils are not heavily limed or that the soils naturally have a consistent calcium content across the land use types. A study by Cross and Schlesinger (1995) also showed minimal differences in Ca-P between forest and agricultural lands in areas with limited external inputs. Organic Phosphorus (Or-P) levels show significantly lower results in bare land with 65.78 mg kg^{-1} compared to cultivated land with 69.45 mg kg^{-1}, and forested land shows 69.43 mg kg^{-1}, with a p-value of 0.034.This showed that Organic phosphorus is usually higher in forest soils due to the accumulation of organic matter from plant residues and litterfall. However, in agricultural lands, organic Phosphorus may experience a decline due to continuous cultivation, although it can remain high if organic inputs like manure or crop residues are returned to the soil. McDowell and Sharpley (2001) found that organic Phosphorus was significantly higher in forested soils compared to cultivated soils due to organic matter cycling. Our result also recorded higher Or-P in cultivated land, indicating that organic inputs or conservation practices are helping to maintain soil organic matter and, consequently, soil Or-P. This is also agreed with the findings by Stewart *et al* (2020) observed that organic phosphorus can remain high in well-managed agricultural soils. The Iron-bound Phosphorus (Fe-P) concentrations from this study show approximately similar results across the land uses, with bare land having 13.040 mg kg^{-1}, cultivated land showing 13.435 mg kg-1, and forested land showing 14.095 mg kg^{-1}. All showed no significant difference with p p-value of 0.22. The results explained that Iron-bound phosphorus (Fe-P) is typically higher in soils with high iron content, particularly in tropical soils where lateritic conditions promote the binding of phosphorus to iron oxides. Studies by Haileslassie *et al* (2011) highlight the prevalence of Fe-P in the tropical soils, particularly in forest ecosystems where redox fluctuations enhance the binding of Phosphorus to iron. The lack of significant differences in Fe-P levels across land uses in this study may indicate that the soils with similar iron content and redox conditions are relatively stable across the land uses. Comparable findings by Nkana *et al* (2020) also showed minimal differences in Fe-P levels between forest and cultivated lands in tropical regions.

The results on the total Phosphorus (T-p) levels are slightly higher in cultivated land with 123.155 mg kg^{-1} followed by forested lands with 122.550 mg kg^{-1}, compared to bare land with 117.045 mg kg^{-1}, and there is no significant difference with value p = 0.11. Total phosphorus represents the sum of organic and inorganic phosphorus fractions in the soil. Several studies have shown that T-p levels tend to increase in cultivated soils due to fertilizer inputs. However, the differences between cultivated and forest soils may not always be significant, especially in regions where phosphorus inputs are moderate. Tiessen *et al* (1984) recorded similar results, where total phosphorus was only marginally higher in cultivated lands as compared to forest soils due to the limited use of phosphorus fertilizers. Similarly, the study by Fanjana *et al* (2017). indicated that T-P can be comparable across land uses.

CONCLUSION

The results of this research study on various phosphorus fractions in soils under different land uses have shown that available phosphorus, calcium-bound phosphorus, and iron-bound phosphorus levels show no significant differences across land uses. This shows that the areas recorded low external phosphorus inputs. Whereas Aluminium-bound phosphorus and organic phosphorus from the study show significant differences, with higher levels in cultivated and forest lands. This is consistent with findings from other studies indicating the influence of pH and organic matter on these phosphorus fractions**.** Total phosphorus levels are slightly higher in cultivated and forest lands but not significantly different, mirroring our findings from areas with moderate phosphorus inputs.

Finally, these results on our findings highlight the significance of land use in shaping soil phosphorus characteristics, which have implications for sustainable agricultural practices, soil conservation, and soil ecosystem health.

Despite the explorative nature of this research, the study was limited to only a few phosphorus forms and land use types. Continued research and monitoring of this soil phosphorus forms across all the land use types are essential for understanding phosphorus and its dynamics in the soil environment will inform land management strategies that promote soil health and agricultural productivity among various land-use types.

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